3. STORAGE FACILITIES, OPERATIONS, AND DESCRIPTIONS

3.1 OVERVIEW

Six storage dams have been constructed in the Yakima River basin. Four of these (Bumping Lake, Kachess, Keechelus, and Cle Elum) are located at the outlets of natural lakes. Clear Lake Dam and Tieton Dam created new reservoirs by inundating portions of the upper Tieton River basin. Numerous fisheries-related impacts are associated with the construction and operation of these storage dams and reservoirs. The five major storage facilities (Clear Lake is a minor facility) store runoff during the Winter and Spring/Summer seasons. This water is released later during low-flow periods in the Summer and Fall seasons for irrigation. The total storage of the five major reservoirs is a little over 1 million acre-feet (MAF), but the total yearly runoff passing through the storage reservoir system averages 1.71 MAF.

The five major reservoirs are operated in a coordinated manner to provide for the needs of the system as a whole. The releases from each reservoir are balanced to meet system-wide irrigation and water demands in conjunction with natural runoff and return flow available in the basin. No single reservoir is designated to supply the needs of one particular area, irrigation district, or Project division. The following table provides some basic information about each of the five major storage reservoirs. The following sections discuss the important operational aspects of each reservoir, the part each plays in supplying Yakima River basin water, and the fishery impacts associated with construction and operation of the facility.

Table 3-1. System Storage Capacity and Average Annual Runoff on September 30

Reservoir	Drainage area ($mi.^2$)	Capacity (acre-feet)	Avg. Annual Runoff (acre-feet)	Ratio of Avg. Runoff to Capacity	September 30 Historical Storage (acre-feet)		
					Minimum	Average	Maximum
Keechelus	54.7	157,800	244,764	1.5:1	4,800	40,500	126,900
Kachess	63.6	239,000	213,398	0.9:1	20,100	107,200	227,200
Cle Elum	203.0	436,900	672,200	1.5:1	12,900	118,000	359,500
Bumping	70.7	33,700	209,492	6.2:1	2,400	7,900	24,600
Rimrock	187.0	198,000	367,966	1.8:1	200	74,500	145,100
System	**579.0**	**1,065,400**	**1,707,820**	**1.6:1**	**51,700**	**357,500**	**660,200**
Period of Record = 1920-1999							

3.2 SNOWPACK, THE "SIXTH RESERVOIR"

The majority of spring/summer runoff is from snowmelt, therefore snowpack is often considered the "sixth reservoir." Because only 30 percent of the average annual total natural runoff can be stored in the storage system, the Project is very dependent upon the timing of spring/summer runoff (snowmelt and rainfall). The early Spring/Summer natural flow is used to supply most river basin demands through June in an average year. In most years, the five major reservoirs are operated so that storage peaks in June (average mid-June, period of record 1940-1999), about the same time the major natural runoff ends.

3.3 RESERVOIR STORAGE CARRYOVER

During the summer/fall period of operations, it is desirable to maximize reservoir storage carryover by the end of irrigation season (October 21). The Yakima River basin storage system is designed to store only the current year's spring/summer runoff and deliver it to meet irrigation demands from July through October. If there is only minimal storage (52,000 acre-feet or 52 kaf) remaining on October 21, then the winter and spring/summer periods of operations require a tighter control over the reservoir releases, lower base river flows, and greater flow variability during these time periods. A maximized storage carryover helps to ease those operations and meet demands during a dry year.

The adverse impacts of the drought year of 1977 were reduced because of favorable carryover storage from 1976. The 1994 drought had significant adverse effects on the fishery and water users because there was virtually no carryover after the drought years of 1992 and 1993. A good carryover allows for better overall flow for resident and anadromous fish downstream.

3.4 KEECHELUS DAM AND KEECHELUS LAKE

3.4.1 General — Keechelus Dam is located at Yakima river mile (RM) 214.5, about 10 miles northwest of Easton. Keechelus Dam is an earthfill structure situated at the lower end of a natural lake and was completed in 1917. It forms a reservoir with a capacity of 157,800 acre-feet, with 152,170 acre-feet available for use. The spillway consists of an uncontrolled crest concrete weir; the outlet works consist of a control tower with a single hydraulically operated slide gate. Keechelus Lake is operated to meet irrigation demands, flood control, and instream flows for fish.

3.4.2 Operations — The water in Keechelus Lake is used in conjunction with the rest of the system to provide a portion of the water supply to meet demands from Keechelus Dam to Sunnyside Diversion Dam (RM 103.8). However, a larger portion of the annual runoff to Keechelus Lake is used, along with that of Kachess Lake, to satisfy Upper Yakima Basin demands. Keechelus Lake also provides some carryover storage in normal water years. The prime flood control season extends from mid-November through mid-June. Irrigation demands are met by releases from Keechelus Lake either through bypassed reservoir inflows (beginning in mid-March) or stored water releases. When the Project is on storage control, diversions above Easton, including those for Kittitas

Reclamation District, are served primarily from Keechelus through late August. During September and October those diversions are satisfied primarily out of Kachess Lake.

Outflows from Keechelus Lake follow an annual pattern of relatively low flows during winter and relatively high flows during the April through late-August irrigation season. At a minimum, beginning in late August, during Mini Flip-Flop, releases from Keechelus Lake are reduced to meet a 60 cubic foot per second (cfs) target streamflow in the Yakima River at Crystal Springs (RM 213); this is based on past commitment and operations by Reclamation and water users.

In October, after spring chinook salmon spawning is complete, streamflows are reduced still further. In practicality, the flow is at least 30 cfs and often somewhat higher, depending on SOAC-presented considerations regarding incubation flows (S. Fanciullo, USBR Yakima, WA, 2003, pers. comm.) The 30 cfs represents a Keechelus Lake release of about 15 cfs with the balance from inflows in the reach between Keechelus Dam and Crystal Springs. If there were no inflows in this reach, the full 30 cfs would be released from Keechelus Lake.

This operation keeps downstream flows confined to the defined low flow channel so that spring chinook salmon will spawn in areas that can be kept watered throughout the winter incubation season. Releases are tangible attempts to keep all the spring chinook salmon redds under water in the reach from Keechelus Dam to Easton Dam (RM 202.5) without jeopardizing irrigation storage supplies. This operation is continued until reservoir releases are increased either due to flood control or to meet irrigation demand.

Currently, during the spawning and incubation period, these instream flows are variable depending upon the forecasted available runoff, and may be increased by the Yakima FOM after consultation with SOAC and the irrigation community. Currently, during Water Year (WY) 2003, the incubation flows are targeted at 80 cfs for Keechelus Lake release and 100 cfs at Yakima River at Crystal Springs (S. Fanciullo, USBR Yakima, WA, 2003, pers. comm.).

3.4.3 Facilities — Keechelus Dam is equipped with an uncontrolled, concrete overflow crest spillway capable of passing 8,000 cfs at elevation 2520.90 feet. The main outlet works has a single hydraulically operated slide gate (8.5 feet by 8.5 feet). The 7-foot maximum gate opening is capable of releasing 3,000 cfs, but the normal maximum release would be 1,500 to 1,700 cfs. This gate (sill elevation 2426.90 feet) has a minimum gate opening of 4 inches in the high head mode (over 33 feet) and 1.5 inches opening under low head mode (under 33 feet). Located in the same outlet works is a 22-inch outlet conduit to bypass minimum flows for fishery and stream enhancement when the main outlet gate is closed. The ramping rate for operations at Keechelus Dam is 2 inches per hour (river stage) as measured at the dam's outflow gage.

The outlet works and stilling basin were rehabilitated in 1976. In mid-1998, it was determined that dam safety deficiencies existed at Keechelus Dam due to the potential for dam failure from piping or internal erosion of embankment materials or both. A reservoir operating restriction to elevation 2510 feet was imposed, together with increased monitoring and surveillance, pending implementation of corrective actions. This operating restriction limits storage to 140,920 acre-feet. The reservoir can be operated above elevation 2510 feet only for the control of large flood events. Corrective actions on the embankment began in April 2002 and are scheduled to be completed by November 2003.

3.5 KACHESS DAM AND KACHESS LAKE

3.5.1 General — Kachess Dam was constructed at the lower end of a natural lake and completed in 1912; it is located on the Kachess River, 2 miles northwest of the town of Easton. The earthfill dam has a structural height of 115 feet and a crest length of 1,400 feet. The spillway consists of a single 8-foot-tall, 50-foot-wide radial gate and a concrete -lined open channel in the right abutment. The outlet works consists of a conduit at the base of the dam controlled by slide gates. The dam impounds a reservoir with a capacity of 239,000 acre-feet, with up to 222,000 acre-feet available for use. Kachess Lake is operated to meet irrigation demands, flood control, and instream flows for fish. The flood control season extends from mid-November through mid-June. Flood space control releases are normally minimal due to the poor refill ratio of 0.9 to 1. (A refill ratio of less than 1 to 1 means a reservoir will not fill in an "average" year if it starts the year empty.)

3.5.2 Operation — Kachess Lake storage is used in conjunction with the rest of the system to provide a portion of the water supply to meet irrigation and water demands from Easton Diversion Dam (RM 202.5) to Sunnyside Diversion Dam (RM 103.8). However, a larger portion of the annual runoff to Kachess Lake is used along with that of Keechelus Lake and Cabin Creek (RM 205) to satisfy Upper Yakima Basin demands. Kachess Lake provides some carryover storage in good water years.

Beginning in mid-March, Upper Yakima Basin irrigation demands are met by releases from Kachess Lake either through bypassed reservoir inflows or stored water releases. When the Project is on "Storage Control" (CC13), diversions above Easton Diversion Dam (including those for Kittitas Reclamation District) are served primarily from Keechelus Lake through late August, which is the start of Mini Flip-Flop. From the start of Mini Flip-Flop and Flip-Flop, the diversions above Easton Diversion Dam and up to 400 cfs of downstream diversion, during September and October, are provided primarily out of Kachess Lake.

Besides supplying a large portion of the system-wide irrigation demands, storage at Kachess Lake is needed to meet fishery resource's winter (incubation and rearing) minimum target flows along the Yakima River reach from Easton Diversion Dam (RM 202.5) to the Teanaway River (RM 176). In addition, when the reservoir is operated to meet multiple instream flow requirements, the high demand on storage water significantly reduces the ability of the reservoir to refill the following season; this is especially true of Kachess Lake, because the average annual runoff is less than reservoir capacity. Therefore, the reservoir does not fill every year even under normal runoff conditions. Kachess Dam minimum outflow during the winter is 5 to 8 cfs (equivalent to gate leakage) unless greater releases are needed for support of the Yakima River target flows.

3.5.3 Facilities — Kachess Dam is equipped with a gated spillway (sill elevation 2254.00 feet), consisting of one radial gate (50 feet by 8 feet high) with capacity of 4,000 cfs at full lake elevation of 2262 feet. The regulating outlet works has three slide gates (4.5 feet wide by 8 feet high) with an 8-foot maximum gate opening capable of releasing 3,690 cfs at full lake elevation. These gates (sill elevation 2192.75 feet) have a minimum gate opening of 0.17 foot and are the main release points for flows that support spawning and incubation in the Yakima River. There is an 18-inch butterfly valve located in the same outlet works at invert elevation of 2195.92 feet. At 25 feet

of head and 100 percent gate opening, it bypasses approximately 35 cfs into the outlet conduit through the valve installed in the outlet works downstream from the main gates. When the main outlet gate is closed, and the auxiliary low flow bypass valve is being used, it is only capable of providing minimum flows for fishery and stream enhancement needs in the Kachess River. Kachess Dam has no fish passage facilities. The ramping rate for operations at Kachess Dam is 2 inches per hour (river stage) as measured at the first gage downstream from the dam.

3.6 CLE ELUM DAM AND CLE ELUM LAKE

3.6.1 General — Cle Elum Dam is located at at the lower end of a natural lake at RM 8.2 on the Cle Elum River, 8 miles northwest of the city of Cle Elum. Construction of Cle Elum Dam was completed in1935. The earthfill dam forms a reservoir with a capacity of 436,900 acre-feet, with 427,930 acre-feet available for use. The dam has a structural height of 165 feet and a crest length of 1,800 feet. The spillway consists of five 17-foot-tall by 37-foot-wide radial gates and a concrete-lined open channel in the right abutment. The outlet works consist of a control tower and concrete-lined tunnel through the right abutment.

3.6.2 Operations — Cle Elum Lake is operated to meet irrigation demands, flood control, and instream flows for fish. The prime flood control season extends from mid-November through mid-June. Cle Elum Lake regulates about 20 percent of the entire runoff above Parker gage (RM 103.7) and is the largest storage facility in the Yakima River basin. Therefore, it is the main resource for meeting the large irrigation demands in the Lower Yakima Basin. The heaviest storage releases for irrigation are during the months of July and August, and it is normal for the main gates to reach hydraulic capacity in mid-August. Cle Elum Lake also provides the majority of carryover storage in normal water years.

In recent years, about 12 percent of the spring chinook salmon redds in the Upper Yakima Basin were found in the Cle Elum River while about 50 percent of the redds were found in the Yakima River reach upstream from the mouth of the Cle Elum River to Easton Diversion Dam. The presence of redds downstream from Cle Elum Dam and in the Yakima River downstream from the mouth of the Cle Elum River results in conflicting needs for the operational releases from the reservoir. Cle Elum releases meet most of the Lower Yakima Basin diversion demands during July and August. The majority of the summer release (3,200 cfs ±) is cut back during Flip-Flop to a minimum flow level (200 cfs) that is adequate to support both spawning and irrigation demands on the Upper Yakima Basin system. The larger portion of the Lower Yakima Basin diversion demands during the spring chinook salmon spawning period (September and October) are met from Rimrock releases. This allows Reclamation to minimize Cle Elum releases to meet a target flow (normally 150 cfs) in the Cle Elum River during the winter for spring chinook salmon incubation and early rearing.

3.6.3 Facilities — Cle Elum Dam is equipped with a gated spillway (sill elevation 2223.00 feet); this consists of five radial gates (37 feet wide by 17 feet high) with capacity of 40,000 cfs at reservoir elevation 2240 feet. The main outlet works has two slide gates (5 feet wide by 6.5 feet high). The 6.2-foot maximum gate opening is capable of releasing 4,600 cfs, but the August normal

maximum would be around 3,400 cfs. The two slide gates (sill elevation 2112.25 feet) have a minimum opening of 0.10 foot, and they are the main support for the spawning and incubation flows. There are two 14-inch gate valves (invert elevation of 2127.09 feet) located in the same outlet works; at maximum head, each valve can only bypass 45 cfs into the main outlet conduit when the main outlet gates are closed. This bypass flow is not sufficient to support the normal spawning or incubation flows in the Cle Elum River reach. Maintenance work to the outlet works tunnel or guard gates requires stop-logging at intake to the tunnel. Currently this would allow no flow into the downstream river. Therefore, this type of required maintenance is attempted only when the lake is above spillway crest (elevation 2223.00 feet). Otherwise, pumping to maintain instream flows would be necessary. Cle Elum Dam has no fish passage facilities. The ramping rate for operations at Cle Elum Dam is 2 inches per hour as measured at the first gage downstream from the dam.

3.7 BUMPING LAKE DAM AND BUMPING LAKE

3.7.1 General — Bumping Lake Dam is located at the lower end of a natural lake at RM 17 on the Bumping River, about 29 miles northwest of the town of Naches. The earthfill dam was completed in 1910 and has a structural height of 61 feet and a crest length of 2,925 feet. The spillway consists of an uncontrolled concrete ogee crest and concrete-lined channel that extends to a wood flume. The outlet works consist of a gate tower and concrete conduit at the base of the dam. The reservoir has a total capacity of 33,700 acre-feet, with 31,220 acre-feet available for use.

3.7.2 Operations — The average annual runoff at Bumping Lake is much more than the reservoir's capacity, which allows it to fill every year. Bumping Lake is normally operated in the "Flood Control" (CC6) mode during the Spring/Summer period, except for extreme water-short years (or multiple short years in a row). Depending on the timing of the runoff, the reservoir can be brought up to full pool a number of times each year. The facility is used to supplement water supply for demands in the upper Naches River during summer months. Until recently, it was also used during the winter months to provide bypass inflow to support the diversion right for the Wapatox Power Plant. Heavy drawdown of storage for summer irrigation demand normally starts in August and continues into early September. Bumping Lake is not used as a carryover facility, but is operated to provide 6 to 9 kaf of end-of-season storage needed to maintain winter incubation flows in the Bumping River.

During the early-September/late-October spawning period, the reservoir's outflows are kept under 200 cfs in order to minimize the required releases from storage for the winter incubation and rearing (I&R) period. During the winter I&R period, natural inflow to Bumping Lake often drops below 35 cfs; to provide winter minimum target flows, supplementation from the carryover storage (currently targeted to 12,000 to 16,000 acre-feet) is required. During the winter I&R period — and depending on earlier spawning flows — instream flows downstream from Bumping Lake Dam are kept at a minimum target of 50 cfs or more. Currently during this period, these instream flows are set by the Yakima FOM after consultation with SOAC (and others) and are variable depending on the results of redd surveys. During WY 2003 the incubation flows were targeted at 180 cfs but due to weather conditions drifted down to 115 cfs, but then increased up due to flood control operations (S. Fanciullo, USBR Yakima, WA, 2003, pers. comm.).

3.7.3 Facilities — Bumping Lake Dam has an overflow crest spillway (elevation 3426.20 feet) capable of passing 3,400 cfs at a reservoir elevation of 3429 feet. The main outlet works has two slide gates (4.5 feet wide by 5 feet high), each with a 5.0 foot maximum gate opening and each capable of releasing 1,240 cfs; August releases usually range from 500 to 700 cfs. The slide gates (sill elevation 3389.00 feet) have a minimum opening of 0.10 foot. They are the only support for the spawning and incubation flow releases; this is because there is no auxiliary low-flow bypass in Bumping Lake Dam. In order to perform maintenance on the outlet works or its guard gates, stop logs are needed at the intake of the outlet works; to perform work in the outlet tunnel, the main gates must be closed. Either action would allow no flow into the river downstream. To maintain instream flows, such required maintenance is attempted only when the lake is above spillway crest (elevation 3426.20 feet); otherwise pumping would be necessary to maintain instream flows. Bumping Lake Dam has no fish passage facilities. The ramping rate for operations is 2 inches per hour, as measured at the first gage downstream from the dam, 0.4 miles away.

3.8 TIETON DAM AND RIMROCK LAKE

3.8.1 General — Tieton Dam is located at RM 21.3 on the Tieton River, about 40 miles northwest of Yakima and was completed in 1925. The dam is an earthfill structure with a concrete core wall. It has a structural height of 319 feet and a crest length of 920 feet. The spillway consists of a concrete-lined open channel in the left abutment with a concrete side channel weir controlled by six 8-foot-tall by 65-foot-long drum gates. The outlet works consist of a tunnel through the left abutment controlled by jet-flow gates. The dam forms a reservoir with a capacity of 198,000 acre-feet at normal full lake, of which 197,800 acre-feet is available for use. Rimrock Lake is operated to meet irrigation demands, flood control, and instream flow for fish. The prime flood control season extends from mid-November through mid-June.

3.8.2 Operations — Releases of 2,700 cfs for flood control or greater during the winter could impact residents along the Tieton River. "Winter Operations & Ice Watch" (CC25) are conducted during the freezing periods of winter (January, February, and March). In order to prevent damage to the spillway structure and gates, the lake surface is held below elevation 2900 feet until the freezing danger is past. To meet irrigation and other flow demands downstream from the dam to the confluence of the Naches and Yakima Rivers, releases ranging from 500 to 700 cfs are made during the summer. In support of the Flip-Flop operation during September and October, releases up to 2,700 cfs are also made to meet Lower Yakima Basin irrigation needs; this allows the releases from the Upper Yakima Basin reservoirs to be reduced and provides a lower stage for spawning flows in the upper mainstem Yakima River. Rimrock Lake provides good carryover storage in normal or better water years. Outflow reductions may be necessary to allow maintenance work requiring river ford access to the canal or fish screens at Yakima-Tieton Diversion Dam.

Currently (2001), fishery interests support a minimum storage pool greater than 30,000 acre-feet, while the TWSA computation supports a 10,000 to 30,000 acre-feet carryover storage. With this in mind, Reclamation tries to maximize carryover storage in Rimrock Lake. At a minimum, to maintain the viability of the fisheries resource and supply the TWSA, 30,000 acre-feet is targeted for

September 30th. From 1996 to 2000, the minimum winter instream flows downstream from Tieton Dam have been between 15 and 50 cfs.

3.8.3 Facilities — Tieton Dam is equipped with a spillway weir controlled by six 65-foot-long by 8-foot-high floating drum gates (down position, invert elevation 2918.00 feet). These have a total capacity of 45,700 cfs at reservoir elevation 2928 feet. The main operating outlet works has two 60-inch-diameter jet-flow gates (invert elevation 2721.50 feet). At maximum opening (95 percent), these gates are capable of releasing 2,760 cfs at normal full lake elevation 2926 feet. When flow demands require operation of both gates at the same time, a minimum gate opening of 2 feet (40 percent) is maintained to allow rock passage. When only one gate is operating, the minimum opening is 4 inches (5 percent), resulting in a 15 to 20 cfs discharge. These gates are the only support for minimum instream winter flow as there is no auxiliary low-flow bypass located in Tieton Dam. Any maintenance work to the outlet works (sill elevation 2766 feet) or guard gates requires stop-logging at the head end of the outlet works to close the outlet tunnel. This allows no flow into the river downstream. This type of required maintenance is attempted only when the lake is above spillway crest (elevation 2918 feet), otherwise pumping to maintain instream flows would be necessary. Tieton Dam has no fish passage facilities. The ramping rate for operations at Rimrock Lake is 2 inches per hour (river stage) as measured at the first gage downstream from the dam, 0.4 miles away.

3.9 CLEAR CREEK DAM AND CLEAR LAKE

Clear Creek Lake provides negligible irrigation flow since it has a small storage capacity (5,300 acre-feet) and is located upstream from Rimrock Reservoir. However, in short water years and to offset irrigation and fishery minimum storage requirements in Rimrock Lake, Clear Creek might provide some benefit to the downstream storage demands. In normal runoff years, Clear Creek Lake is operated to maintain an elevation greater than 3011.40 feet for Project uses, including fish passage and recreation. Inflow and outflow are essentially equal and most all flow passes over a spillway weir crest at elevation 3011.00 feet. For the past 20 years, one 36-inch slide gate has been kept open 6 inches to prevent the outlet gate area from silting up. From mid-August to October 5th, Reclamation attempts to hold the lake at elevation 3011.40 feet; this provides the most effective passage through the fish ladder and maintains stable downstream spawning flow. In years of late-season, high-volume runoff, this elevation is nearly impossible to hold unless large releases are made through the dam's slide gates; this is undesirable because the fish are attracted by the high gate releases and away from the spillway flows which supply the fish ladder passage.

The majority of operations functions occurring at Clear Creek Lake involve a short water year when it is possible to provide some benefit to the low storage pool in Rimrock Lake. The use of Clear Creek Lake storage occurs when Rimrock Lake's September 30th storage drops below 34,000 acre-feet. Advance notice of intent to drawdown the lake must be given by August 10th to the Wenatchee National Forest so that timely notification may be given to recreation interests to protect facilities around the lake. After October 5th and concluding by October 20th, it is possible to transfer 2,200 acre-feet of Clear Creek Lake storage to Rimrock Lake for operational use by irrigation or fishery

minimum pool demands. Increased outflows from the reservoir do not start until after October 5th because of the risk of kokanee spawning in the higher outflows. After October 20th, Clear Creek Lake can be refilled by closing the outlet gates, but incubation flows are maintained downstream from the dam based on September spawning flows.